THE EFFECT OF VARIOUS KINDS OF ARTIFICIAL ILLUMINATION UPON COLORED SURFACES

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It is a well known fact, even to the casual observer, that colored surfaces appear of a different color under artificial illumination. Especially is this true of certain blues and greens, which appear as greens and blues when illuminated by the oil lamp.

The object of the present investigation is to measure the change in color which takes place when various colored surfaces are illuminated by the various kinds of artificial illumination now in common use: *e. g.*, oil lamp, gas jet, candle, incandescent and arc electric lamps, and Welsbach burner: all of which are compared with daylight.

The colors to be measured were compared by means of color-wheel mixtures on two concentric color-wheels. A portion of each wheel was illuminated by the lights in question, an area of 2cm. square being blocked off by means of a screen, and diffused light being excluded by means of diaphragms. All kinds of artificial illumination were made equal in intensity to that of daylight, which was reflected from an open window by means of a heliostat. The intensities were made equal by varying the intensity of the artificial light to be compared. This was done by varying the distance of the light from the illuminated surface. An even illumination over the entire colored surface was obtained by sending both lights through ground glass. The intensity, thus obtained, was approximately that of one thousand candles at the distance of one metre. No other intensity of illumination was used.

The colored discs used on the color-wheel were prepared in the following way. Six pigments, viz., English Vermilion, Mineral Orange, Chrome Yellow, Emerald Green (Paris Green), and Artificial Ultramarine, were mixed in gum-arabic and applied to the discs by means of a brush. After this, the paper while yet wet was dusted with the paint powder. We thus obtained very good colors. These colors were then defined by comparing with spectral lines in the following way. A spectroscope was used, in which all but one color was cut off by means of a screen in the observing telescope; we thus avoided contrast effects, and isolated one color line for comparison. This color would change as the observing telescope was moved and the color thus projected could easily be compared with the colored paper held in the hand. Three com-

parisons were made in the case of each color, the averages and average variations being calculated. This must be regarded as only a rough test of hue, and is not meant to refer to the actual light-composition of the stimuli used. A photometric determination of the intensity of these colored discs is given in one of the tables, the method of measurement being that of the flicker photometer. The intensities of illumination were varied by varying the distances of the light from the rotating discs. The standard white of the flicker photometer was then compared in the same way with the intensity of magnesium oxide, and finally all results were reduced to this standard.

The following tables give the value of six colors illuminated by daylight of which the definition is stated in terms of the same color illuminated by artificial light. Thus by substitution it would be possible to find the value of any color by artificial illumination in terms of the same color by daylight with certain additions.

The tables give the averages and average variations, ten measurements being made in each case. Following the tables will be found a diagram showing in a graphic way the changes in wave length of each of the standard colors caused by the use of artificial lights. The average variations are given in parenthesis, and when only two discs were used (the variation being symmetrical) but one variation is given.

INCANDESCENT	ARC
85.7 R + 14.3 B	(1.3) = R
R	(2.0) = 1.92 Orange + 98.08 R
5.72 R + 94.28 Orange	(.76) = Orange
Orange	(1.08) = .99Y + 99.01 Orange
52.4 G + 47.6 Y	(.1) = Y
Y	(.1) = 32.4 Orange + 67.6 Y
44.0 B + 56.0 G	(1.8 B) = 63.9 G + 36.1 Bk. (1.3 G)
66.37 G + 1.94 Y + 31.69 Bk.	= G
(1.07G) (1.2Y) (0.8 Bk.)	
59.46 B + 40.54 G	(1.44) = 31 B + 69 Bk.
96 B + 4 W	(.21 B) = 16.89 B + 3.09 R + 80.02 Bk.
	(.12 R) (.24 Bk.)

INCANDESCENT	OIL
91.8 R + 8.2 B	(6.2) = R
R	(.9) = 90.1 R + 9.9 Orange

78.3 Orange + 21. 7 R	(.9) = Orange
Orange	(.8) = 95.72 Orange + 4.28 Y
77.4 Y + 22.6 Orange	(.8) = Y
Y	(1.1) = 82.1 Y + 17.9 G
49.9 Y + 50.1 G	(.65) = G
G	(.8) = 73.0 G + 27.0 B
98.96 B + 1.04 R	(1.8) = B
B	(1.4) = 98.98 B + 1.02 G

Incandescent	Gas
99.6 R + 0.4 B	(.13) = R
R	(.22) = 99.5 R + 0.5 Orange
99.5 Orange + 0.5 Y	(.27) = Orange
Orange	(.33) = 99.6 Orange + 0.4 R
94 Y + 6 G	(.15) = Y
Y	(.7) = 95 Y + 5 Orange
91 G + 9 B	(.8) = G
G	(.12) = 98.1 G + 1.9 Yellow
98.1 B + 1.9 G	(.18) = B
B	(.17) = 99.4 B + 0.6 R

Incandescent	Daylight
84 R + 16 White	(1.2) = R
24 White + 76 Orange	(.7) = Orange
43 Y + 57 G	(.9) = Y
Y	(.8) = 36 Y + 64 Orange
45 G + 55 B	(1.5) = (.6) 4 G + 96 Black
G	(.6) = 91 G + 9 Y
95 B + 4 G + 1 W	= 13 B + 87 Bk.
(.4) (.1) (0.8)	= (.6)
B	= 49.2 B + 1.6 R + 49.2 Black
	(1.6) (1.1) (1.56)

Incandescent	Candle
99.2 R + 0.8 Orange	(.28) = R
R	(.29) = 99.3 R + 0.7 B
99.1 Orange + 0.9 R	(.31) = Orange
Orange	(.60) = 97.7 Orange + 2.3 Y

83 Y + 17 Orange	(.16) = Y
Y	(1.1) = 20 G + 80 Y
97.9 G + 2.1 Y	(.52) = G
G	(.73) = 97.4 G + 2.6 B
98.0 B + 2.0 R	(.64) = B
B	(.46) = 98.1 B + 1.9 G

INCANDESCENT	WELSBACH
55 R + 45 Bk.	(1.1) = R
R	= 54 Orange + 7 Y + 39 Bk (1.2) (0.5) (1.1)
54 Orange + 46 R	(2.0) = (1.5) 53 Orange + 47 Bk.
Orange	(.10) = 47 Orange + 53 Y
62 Y + 38 Bk	(1.0) = (1.1) 54 Y + 46 G
36 Y + 64 G	(1.3) = 50 G + 47 Bk + 3 White (1.1) (1.1) (.6)
G	= 69 G + 6 Y + 25 Bk. (1.2) (.8) (1.3)
94 B + 6 G	(0.8) = (1.5) 38 B + 62 Bk
B	(0.5) = (.5) 93 B + 3 R + 4 Bk. (.2)
84 B + 16 G	(0.4) = B

Intensity of standards, in terms of standard white used in experiments and of oxide of magnesium :—

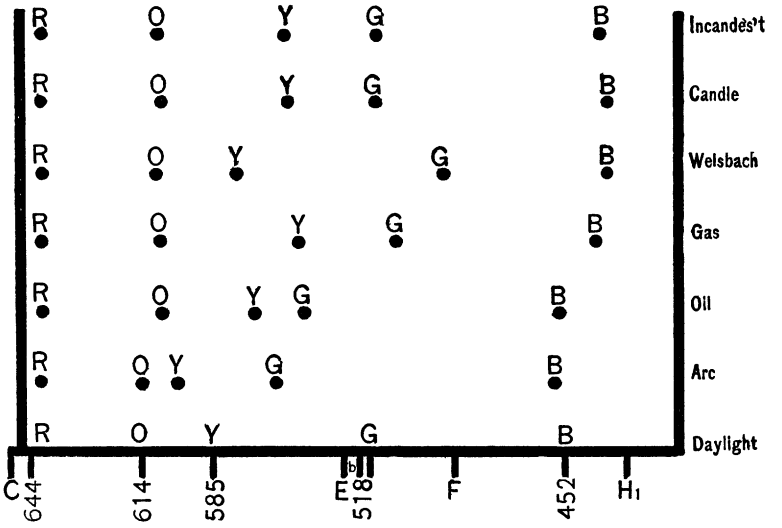
Color	Red	Orange	Yellow	Green	Blue	Black	White
Wave-length	616	604	546	535	447		
Intensity in terms of standard white	28.9	32.0	56.7	17.8	2.9		
Average variation	1.14	2.00	1.56	1.44	0.50		
Intensity in terms of magnesium oxide	26.7	29.4	52.2	16.4	2.7	8.2	92.0 + 1.3

Color-wheel definition of white under arc lamp illumination :—Gray (white) = 16 White + 84 Bk = 14.1 R + 66.1 G + 19.8 B.

CHECK UPON PHOTOMETRY.

Intensity of R + G + B = 26.4 %
" " Bk. + White = 23.5 %

Difference in intensity = 2.9 %


R O Y G B Incandes't
R O Y G B Candle
R O Y G B Welsbach
R O Y G B Gas
R O Y G B Oil
R O Y G B Arc
R O Y G B Daylight
C 644
614
585
E 518
F
452
H1